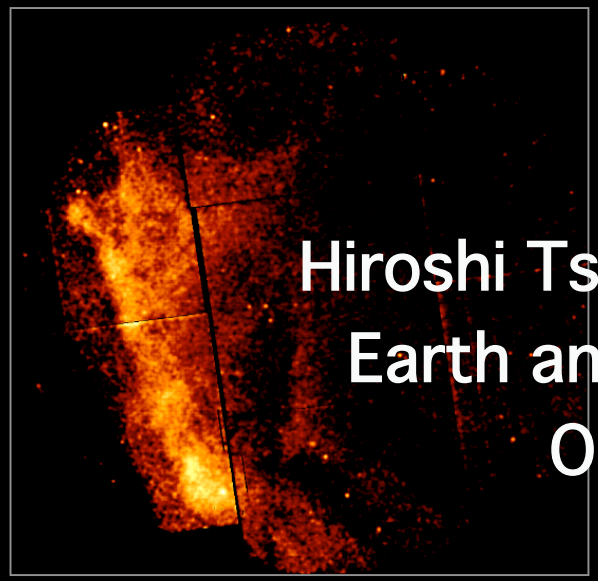
Observation of the shrapnel D near the Vela SNR



First Constellation-X Spectroscopy Workshop
Columbia University
New York, NY
4 - 7 May 2003

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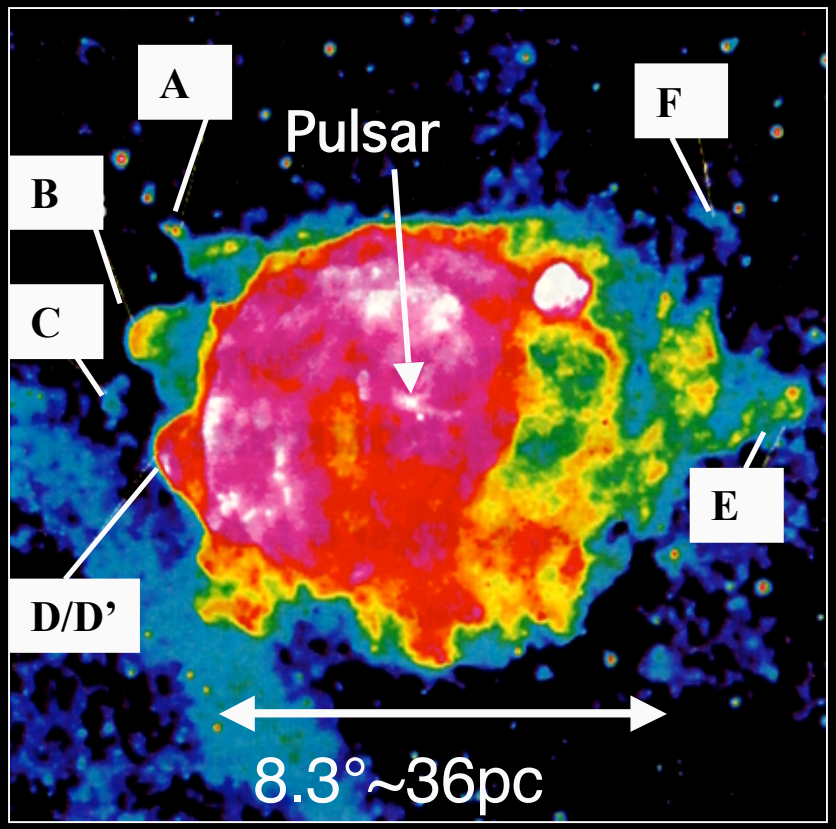
Osaka university, Osaka, Japan

Talk plan

- Observation of the shrapnel near the Vela SNR
  - ROSAT
  - ASCA
  - Chandra
- Observation of the shrapnel D by XMM-Newton
  - Comparison with non-X-ray observation
  - ISM or ejecta (judging from abundance)
  - Temperature and electron pressure
- Summary

Vela SNR and its surrounding



ROSAT image

Vela SNR

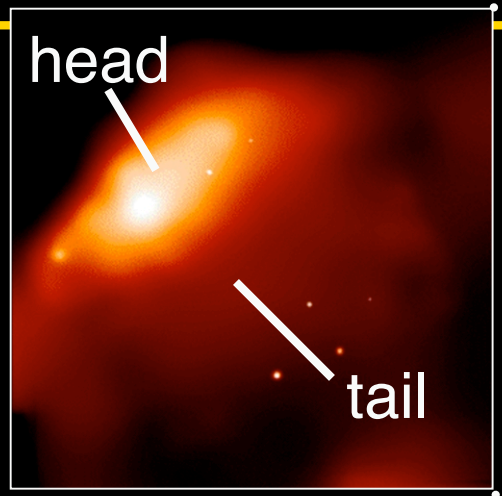
- Distance : 250pc
- Age : ~ 10000 years
- Pulsar in its center (type II SN)

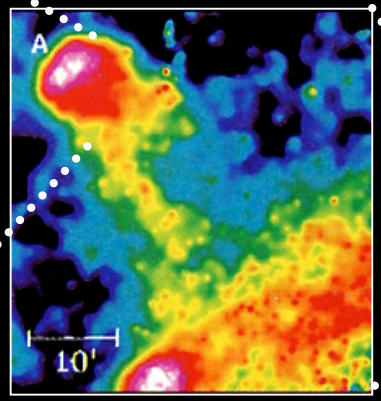
RASS (Aschenbach et al. 1995) revealed the entire structure of the SNR

- Cusp shape structures are out of the main shell.
- Their structures remind us the bullet of the explosion of the SN

Shrapnels in Vela SNR

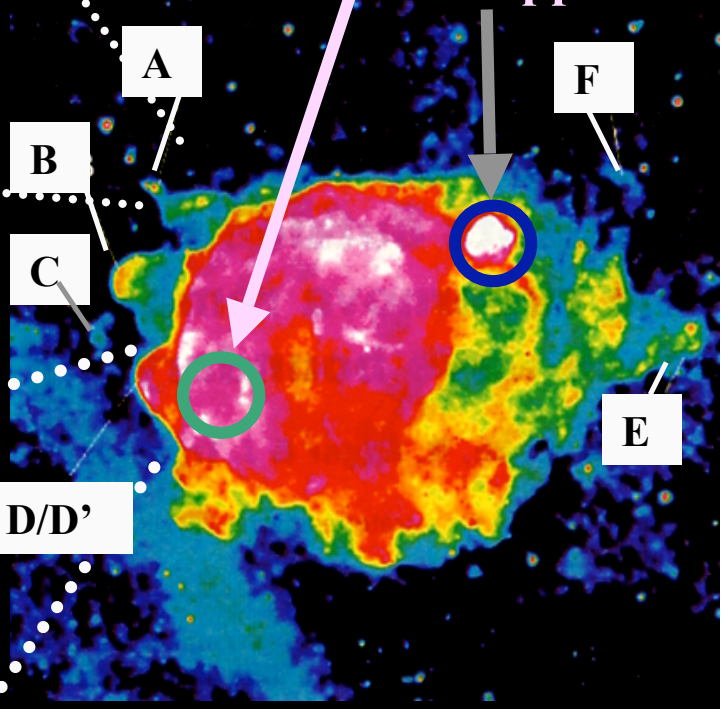
Miyata et al., 2001
Chandra image





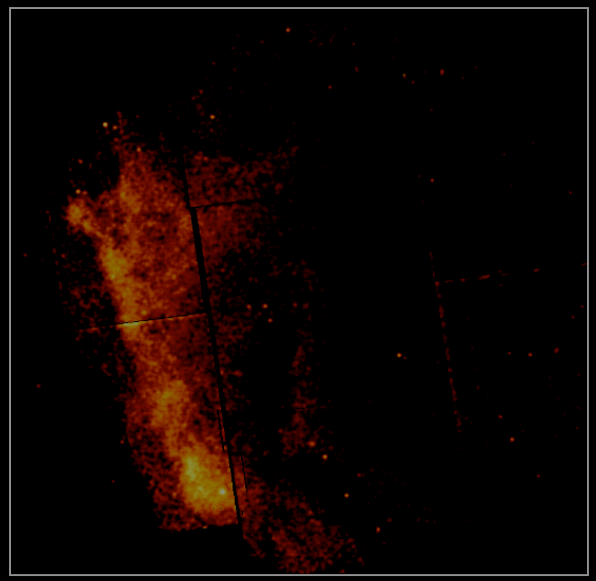
Possible ^{44}Ti candidate
RXJ0852.0-4622

Puppis A

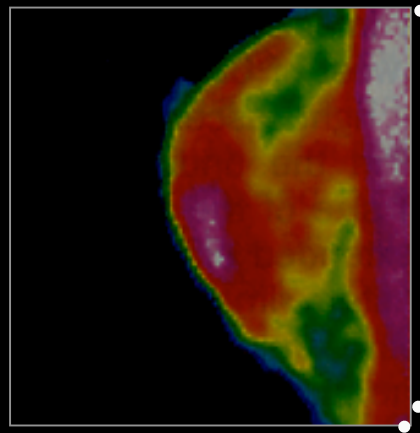


Rosat image

30' circle



Newton XMM image



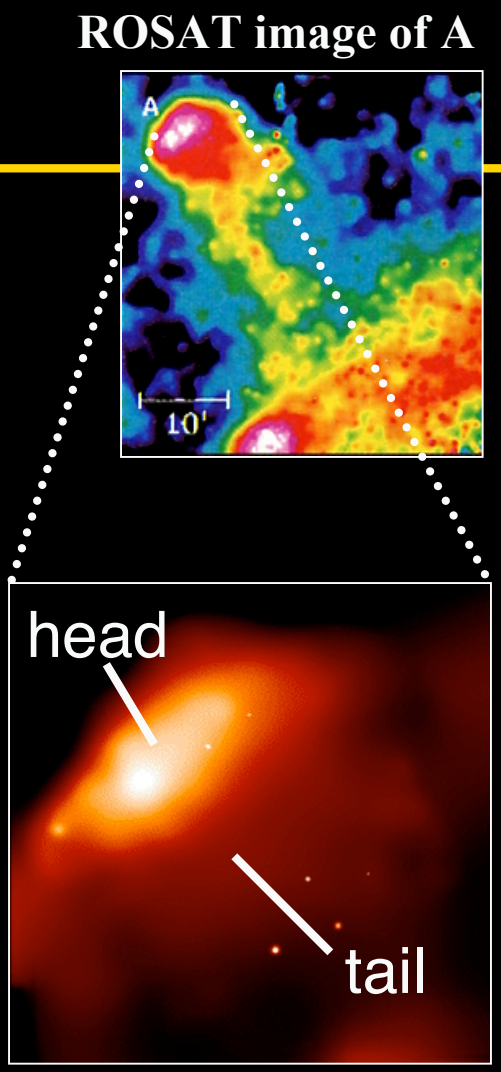
Observation

Aschenbach et al., 1995

Shrapnel A

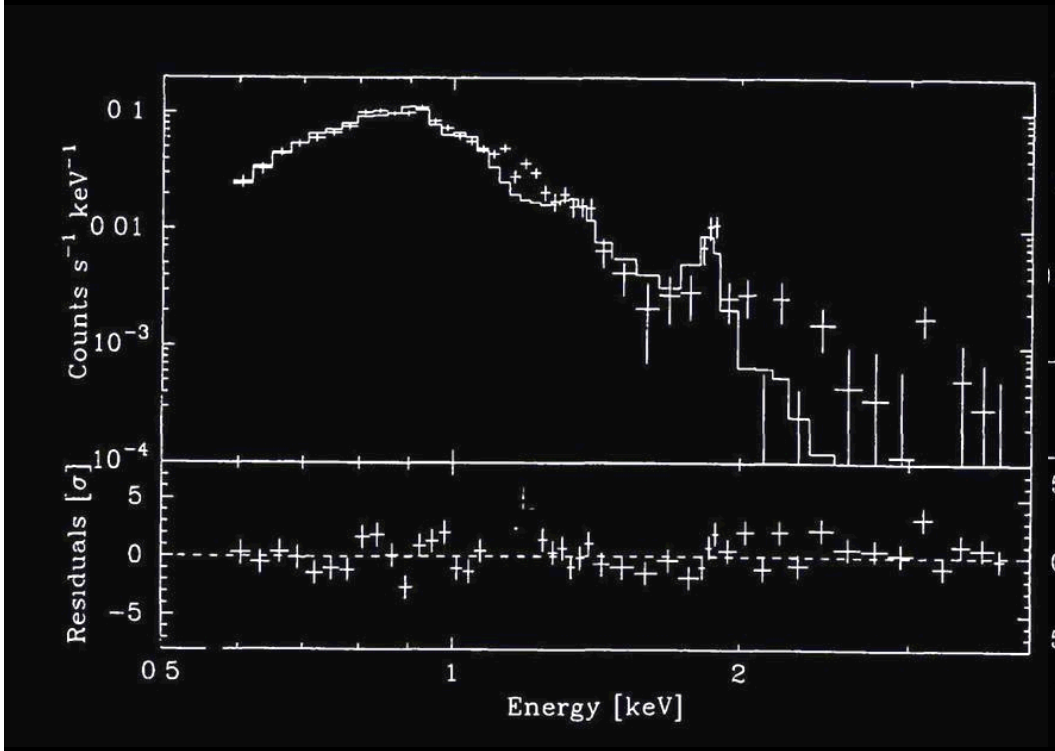
- ASCA observation
  - Tsunemi et al. 1999
- $kT_e \sim 0.33$keV
- Abundance Si~1.5, others ~10^{-2}
- Mass ~$0.01 M_8$

- Chandra observation
  - Miyata et al. 2001
- Bright region (head) and dim region (tail)
- Abundance Si ~ 3 , O ~ 0.34

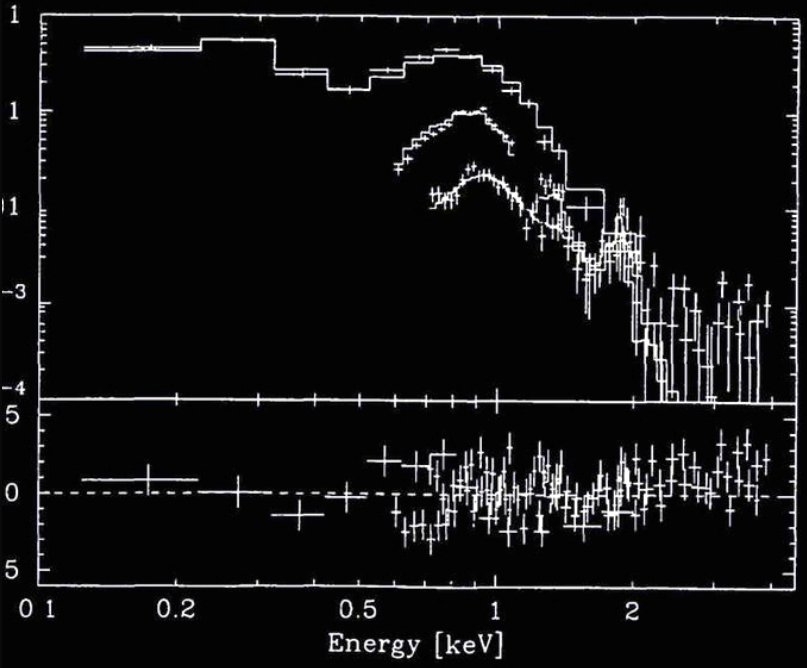


- It shows high abundance of Si compared with that of O.
- It suggests the origin of the ejecta of the SN.

ASCA observation (shrapnel A)

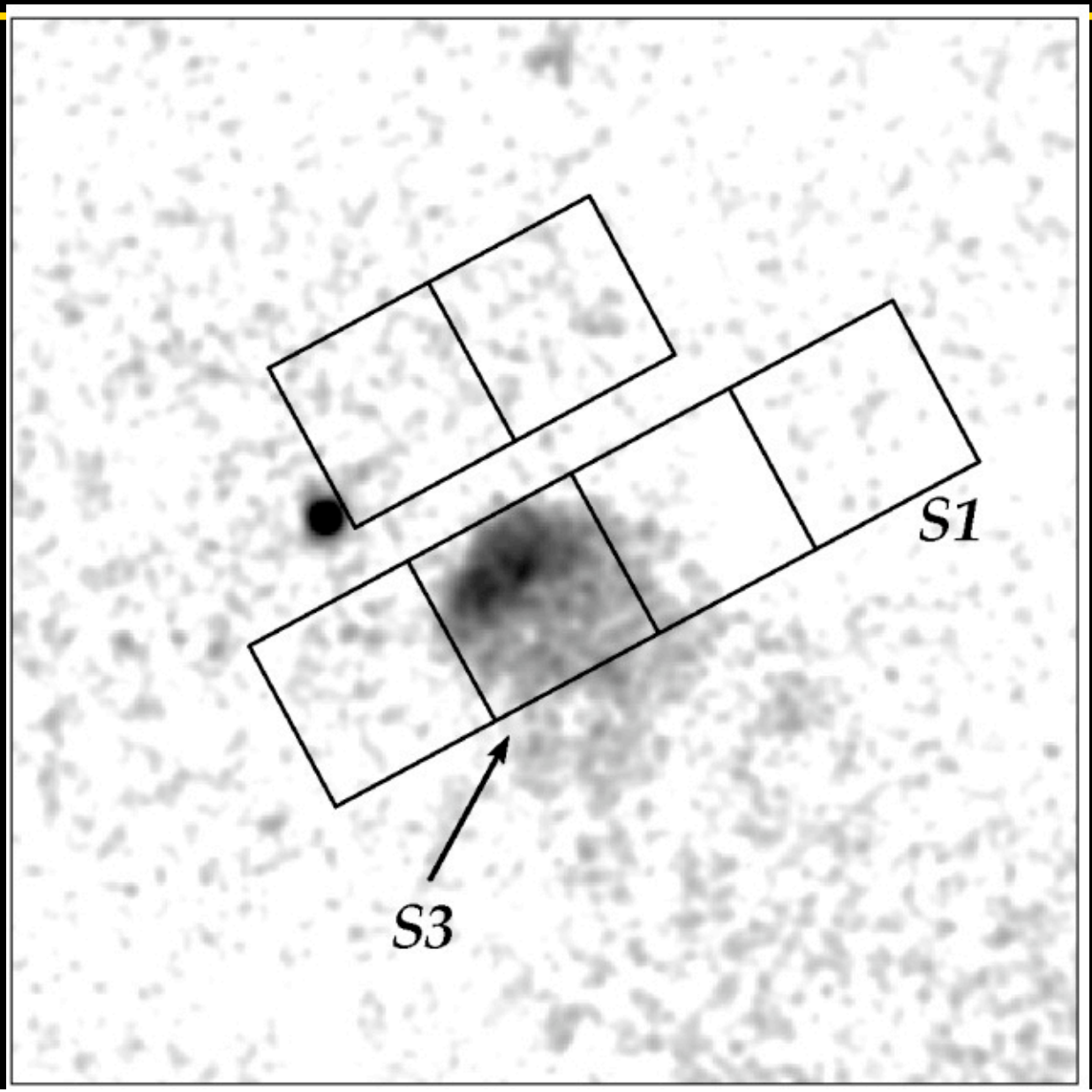


Model fit ignoring the region between 1 – 1.2 keV

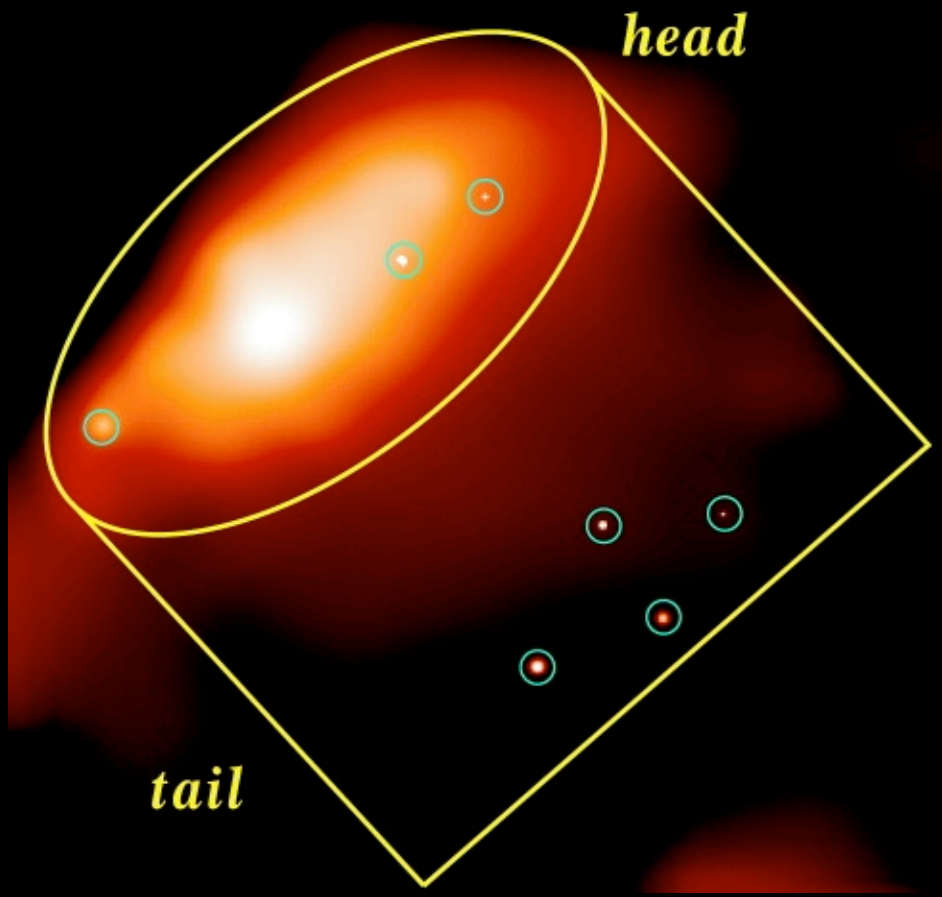


Combined fit for the SIS, GIS and the PSPC

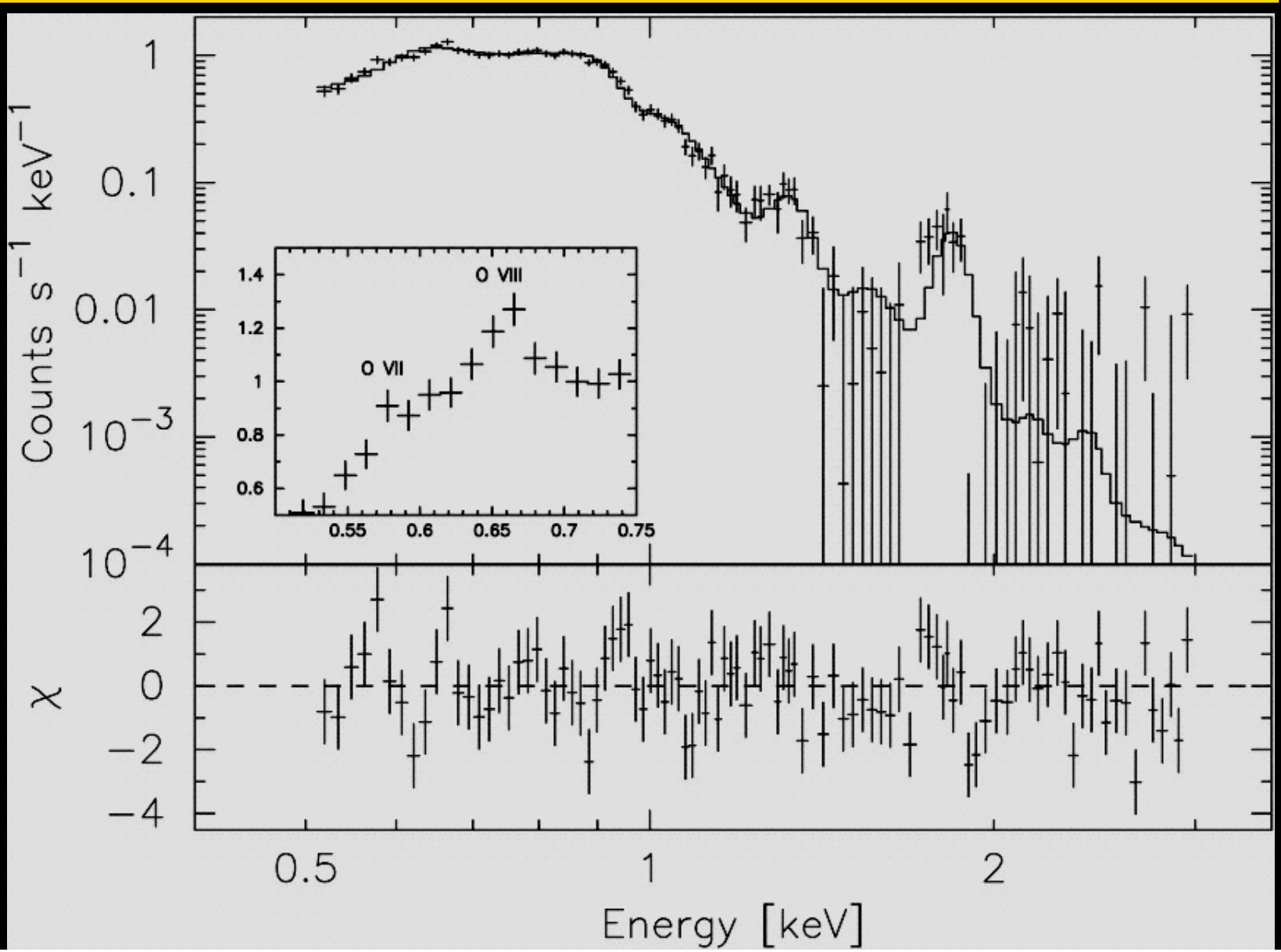
Chandra observation (shrapnel A)



Chandra observation (shrapnel A)



Chandra observation (shrapnel A)



Results for shrapnel A (abundant of Si)

ASCA

Model	Red. χ^2 (d.o.f.)	kT_e [keV]	C,N,O	Ne	Mg	Si
1-kT_e cosmic	13 (83)	0.40	1†	1†	1†	1†
2-kT_e cosmic	2.7 (81)	0.21/0.78	1†	1†	1†	1†
1-kT_e variable	1.9 (77)	0.32	2×10^{-2}	8×10^{-2}	2×10^{-2}	0.5
1-kT_e with variable model						
SIS#	1.3 (72)	0.31 ± 0.02	$3^{+3}_{-2} \times 10^{-2}$	$0.15^{+0.09}_{-0.05}$	$0.11^{+0.1}_{-0.06}$	$1.0^{+0.5}_{-0.3}$
GIS	1.4 (108)	$0.28^{+0.01}_{-0.03}$				
PSPC¶	2.0 (16)	$0.26^{+0.02}_{-0.01}$				
Combined♮	1.5 (199)	0.30 ± 0.02	$5^{+4}_{-2} \times 10^{-2}$	0.2 ± 0.1	0.2 ± 0.1	$1.5^{+0.8}_{-0.5}$

*The quoted errors are at 90% confidence level.

Chandra

Region	kT_e keV	log (τ)	N_H 10^{20} cm^{-2}	C, N, O	Ne	Mg	Si
head	$0.48^{+0.05}_{-0.10}(^{+0.06}_{-0.10})$	$11^{+0.2}_{-0.1}(^{+0.2}_{-0.2})$	< 9 (< 10)	$0.5^{+1.5}_{-0.1}(^{+1.5}_{-0.2})$	$1.7^{+3.2}_{-0.6}(^{+70}_{-0.9})$	$1.3^{+0.7}_{-0.5}(^{+70}_{-0.8})$	$3^{+2}_{-1}(^{+4}_{-2})$
tail	$0.52^{+0.2}_{-0.1}(^{+0.2}_{-0.2})$	$10.9^{+0.3}_{-0.1}(^{+0.4}_{-0.2})$	< 7 (< 9)	> 1 (> 1)	> 3 (> 3)	< 25 (< 30)	< 35 (< 90)

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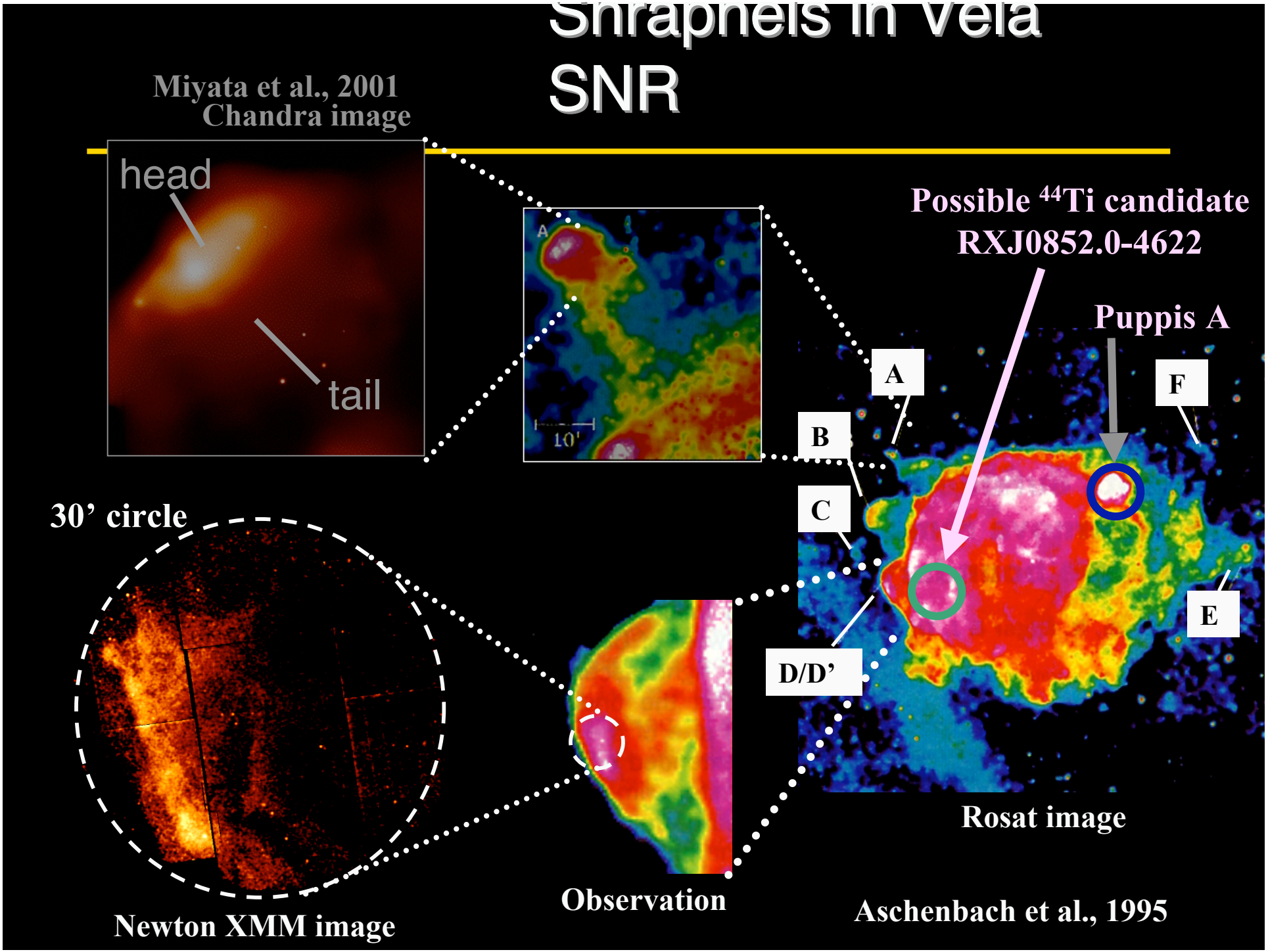
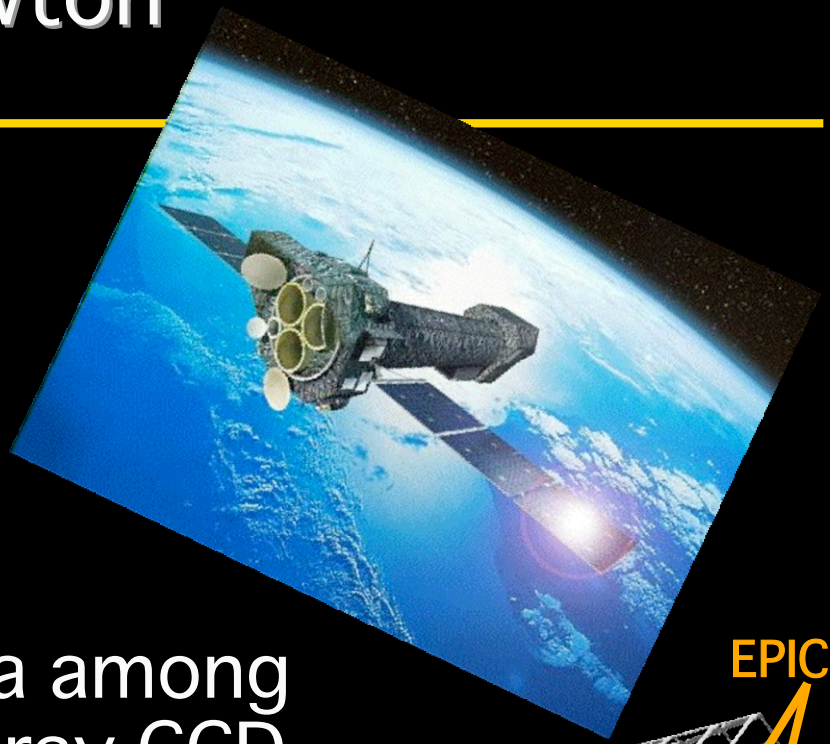
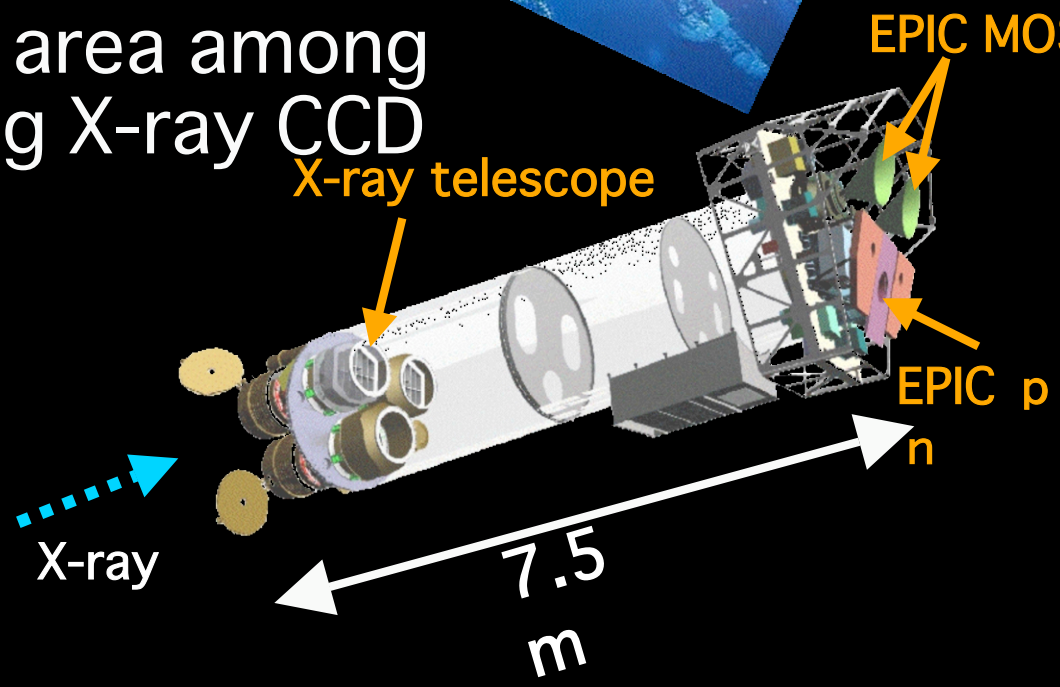
Shrapnels in Vela SNR



Observation of the Shrapnel-B by XMM-Newton

- X-ray CCD
  - EPIC MOS
  - EPIC pn
- Effective area
  - Largest effective area among the satellites using X-ray CCD

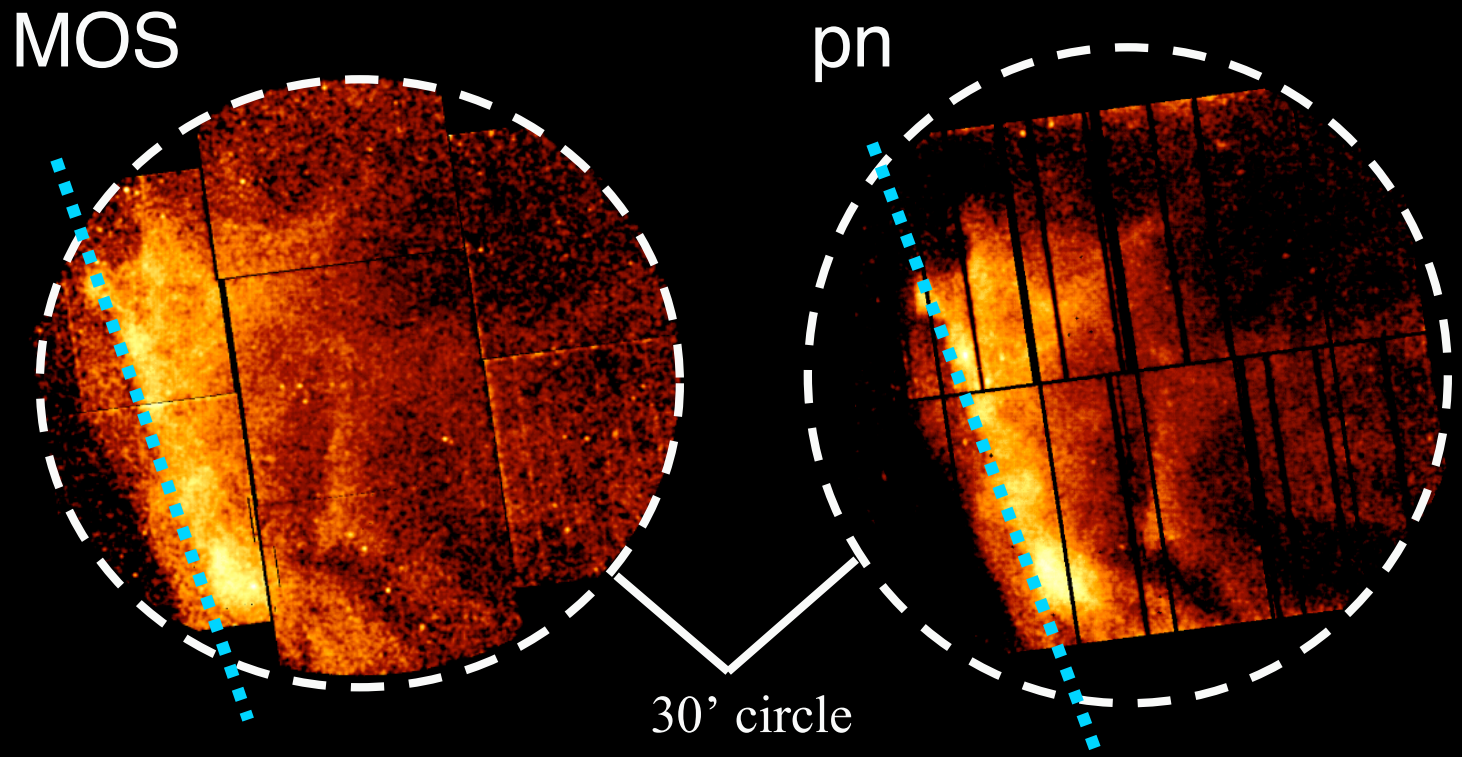




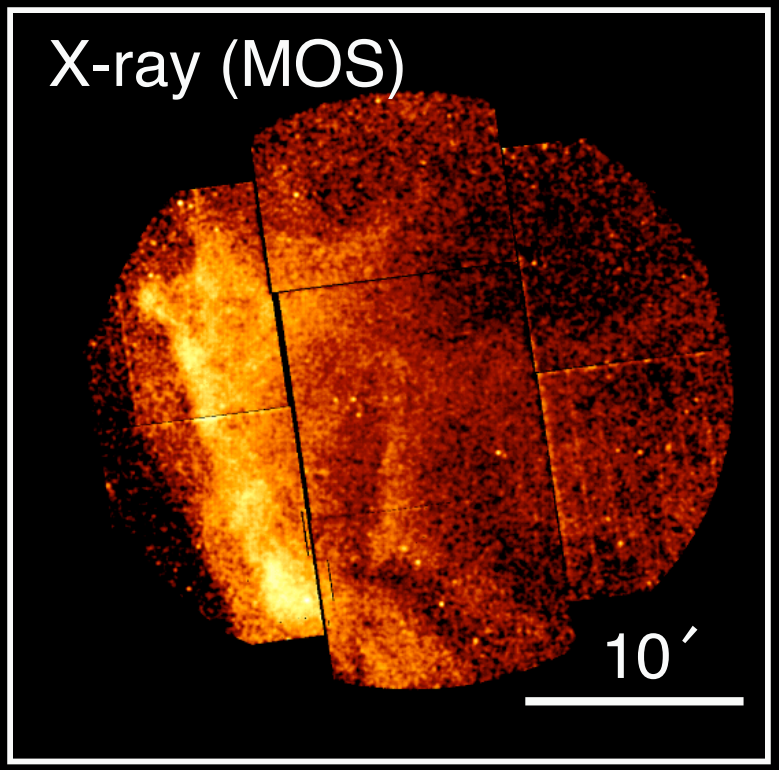
Effective area

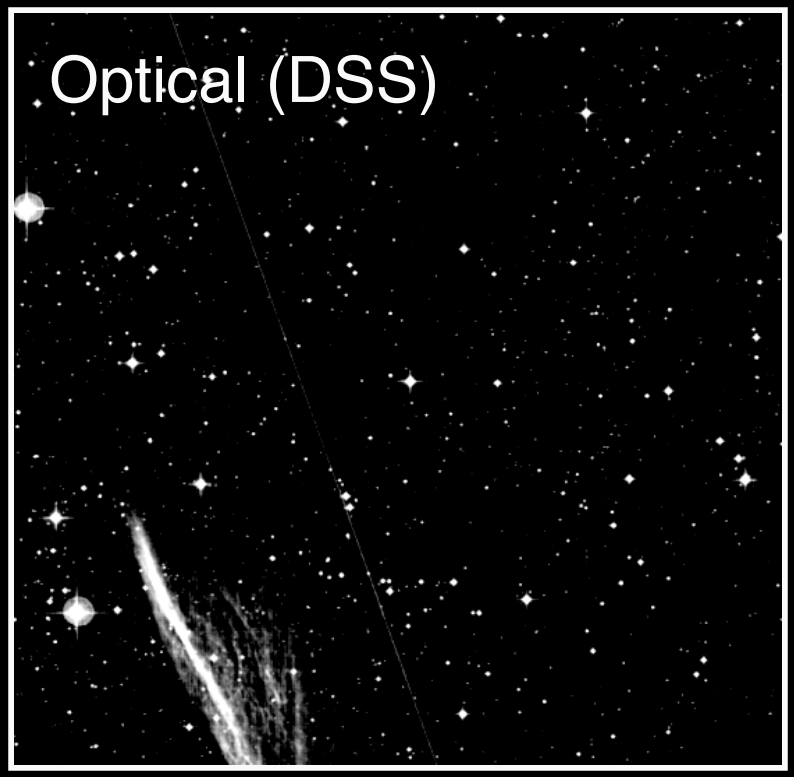
ASCA	350cm^2
Chandra	800cm^2
Newton	4,650cm^2

X-ray image of the shrapnel D



Comparison of X-ray image with that of optical

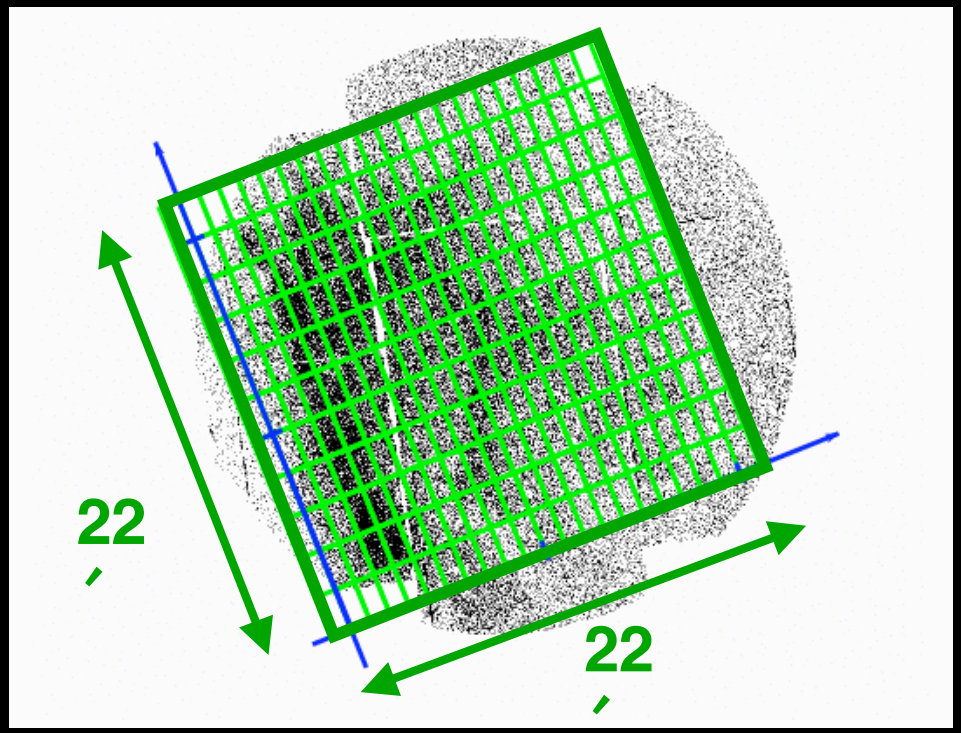




- There is a straight filament in the eastern edge of the shrapnel D.
- Optical filament coincides with the X-ray ridge
  - X-ray intensity change is parallel to the optical filament
- We analyzed the data referred to the optical filament.

We divided the region into small pieces

We extracted the spectrum from each piece.



- We set the coordinates according to the optical filament.
- Each piece is 2’ x 4’
- Each piece overlaps with neighbors by 1’ x 2’
- There are 210 pieces.

Image : MOS

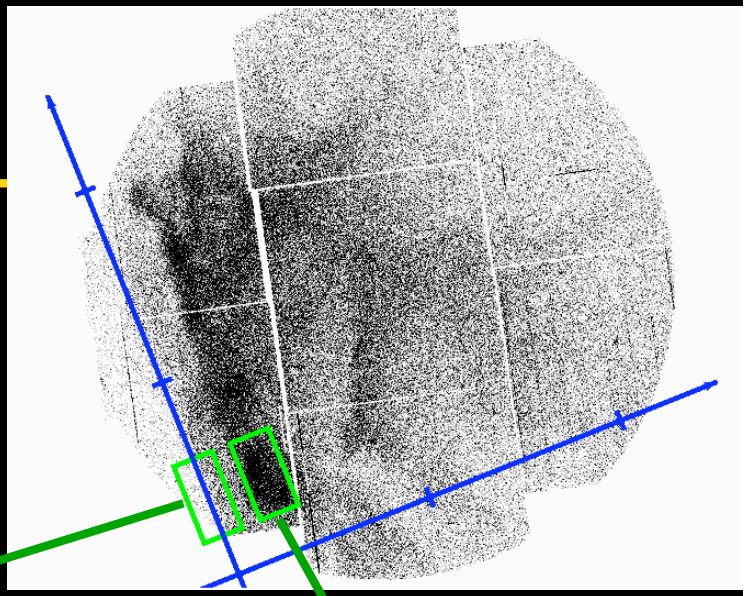
Contour : optical

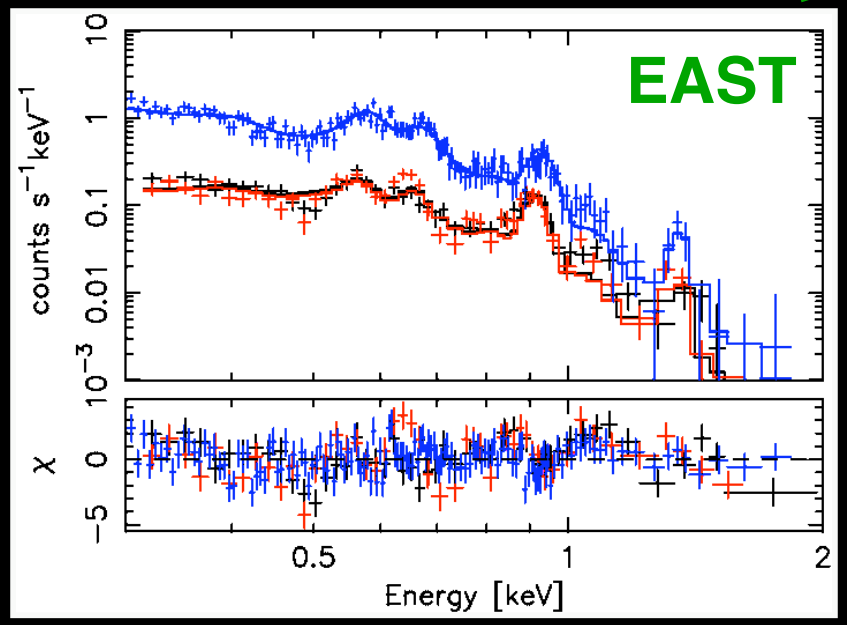
Example of the spectra

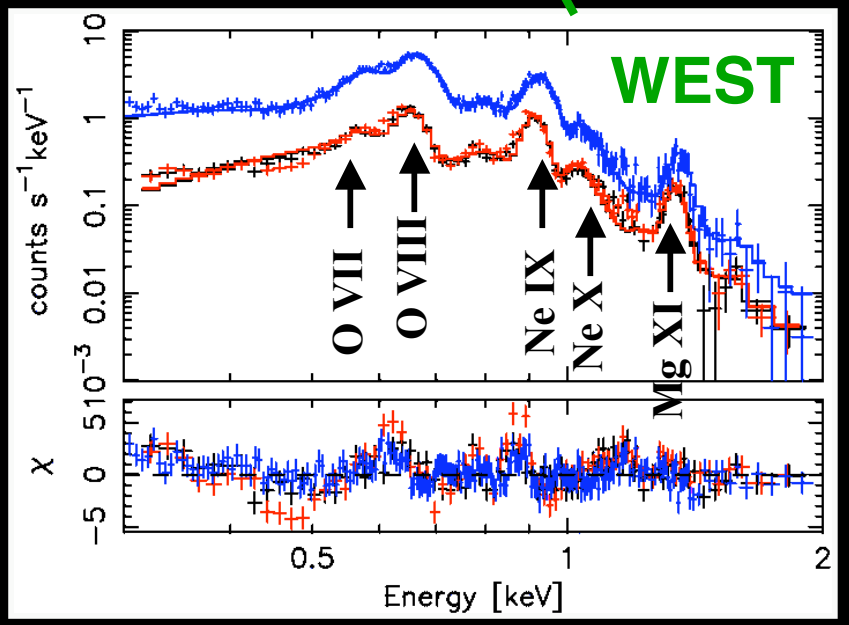
Thin thermal emission fits the data

Abundance is different from east to west

ISM (~1) and ejecta (~several)



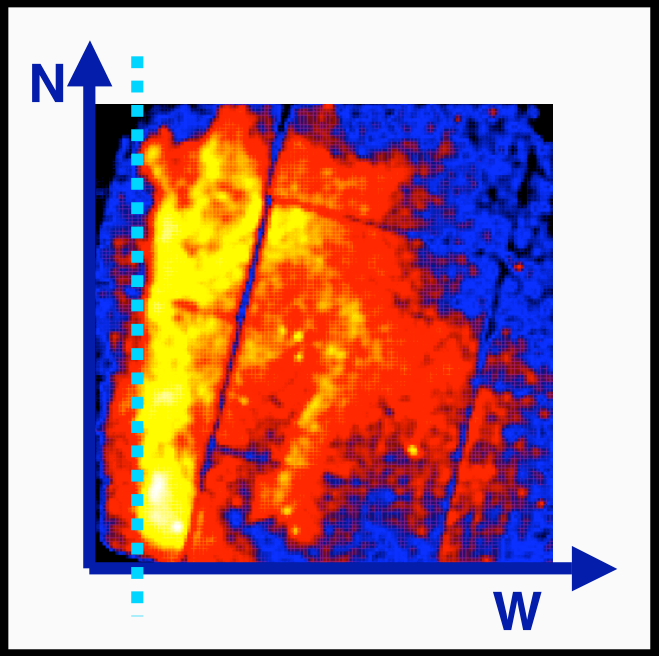




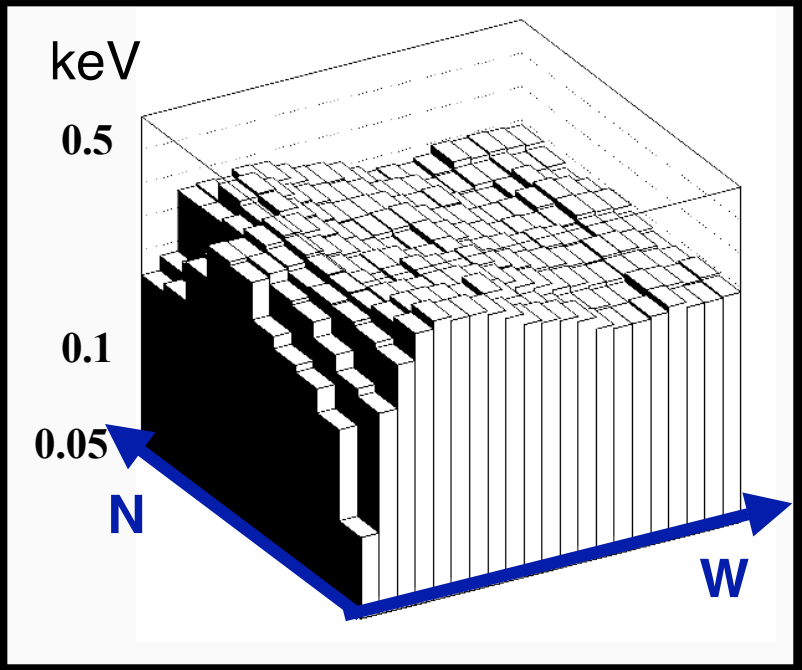
- MOS1 MOS2 pn

Temperature distribution

X-ray image

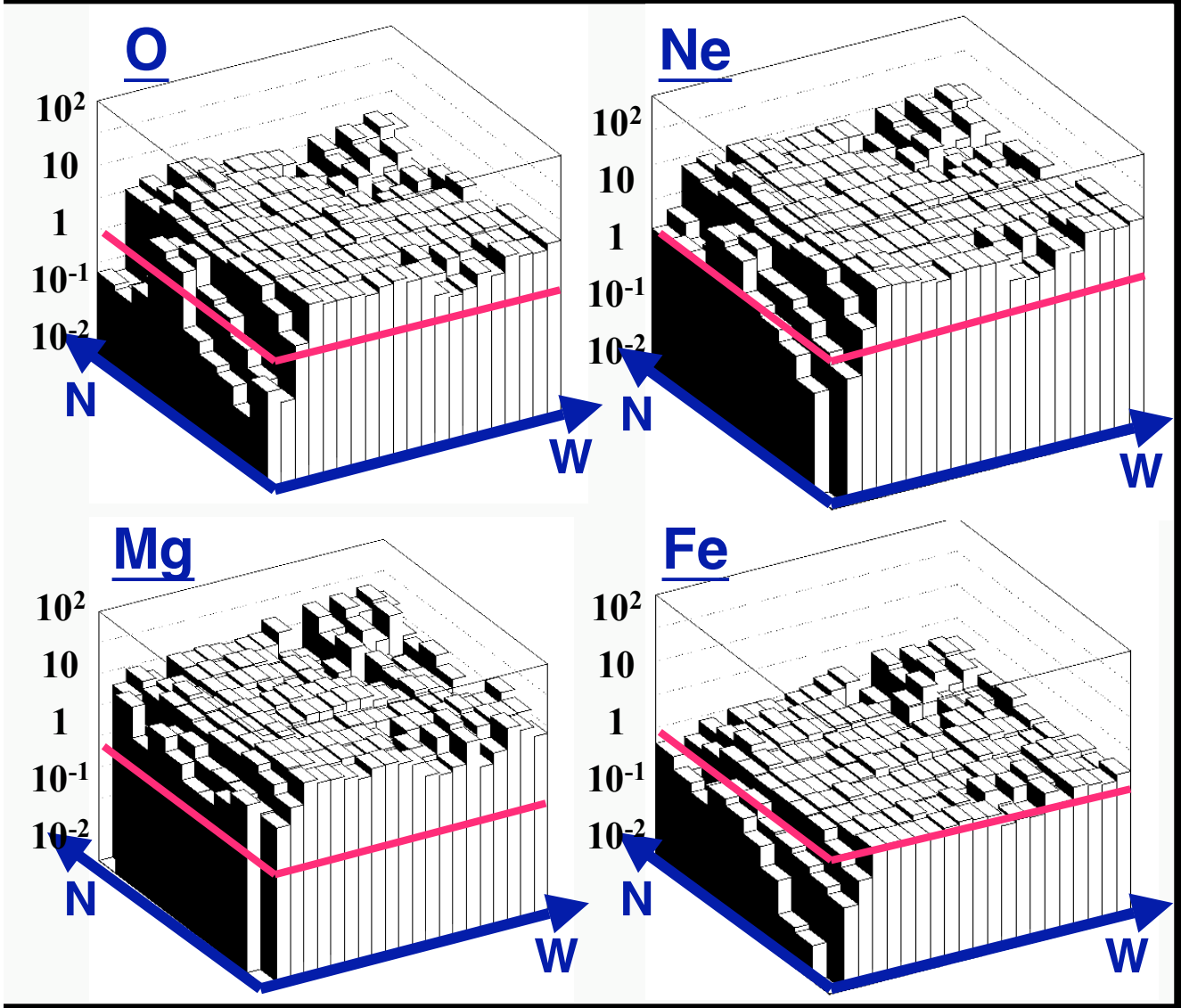


Temperature



- Western part of the discontinuity shows a constant temperature ~ 0.3keV
- Eastern part of the discontinuity shows cooling down to ~ 0.2keV where the edge of the FOV

Abundance distribution



- Western part

  O ~5, Ne ~10

  Mg~10, Fe~1

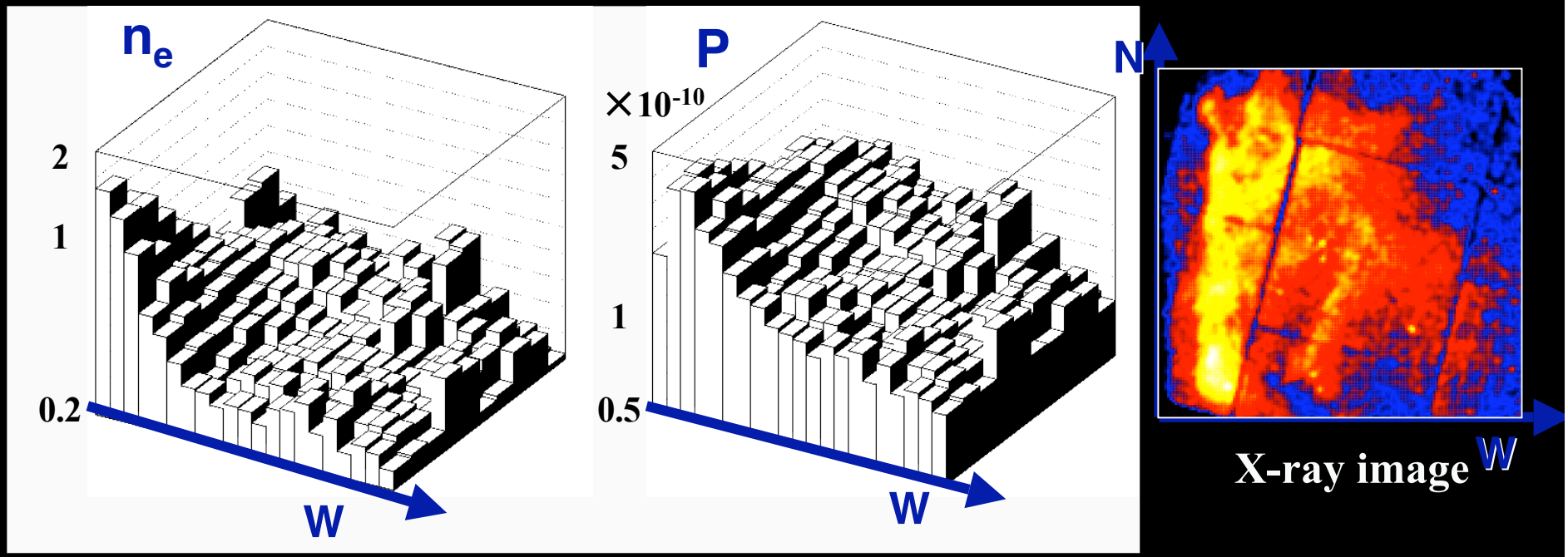
  ⇒similar to that of the type II SN

- Eastern part

  Cosmic or sub-cosmic

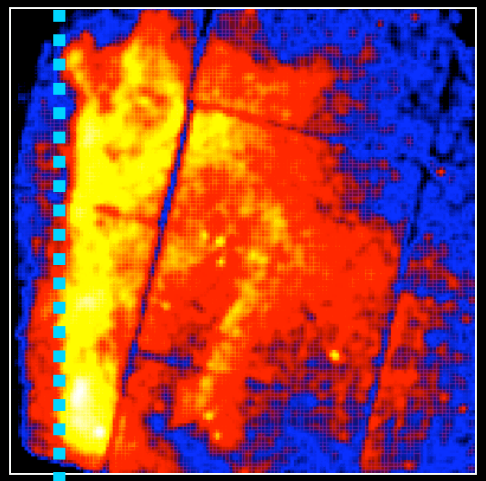
  ⇒similar to that of the ISM

Density (n_e), pressure (P)



- Density and pressure increase eastwards (outside the Vela SNR).
  - This suggests that the swept-up matter is compressed to some extent

Summary of the spectral analysis



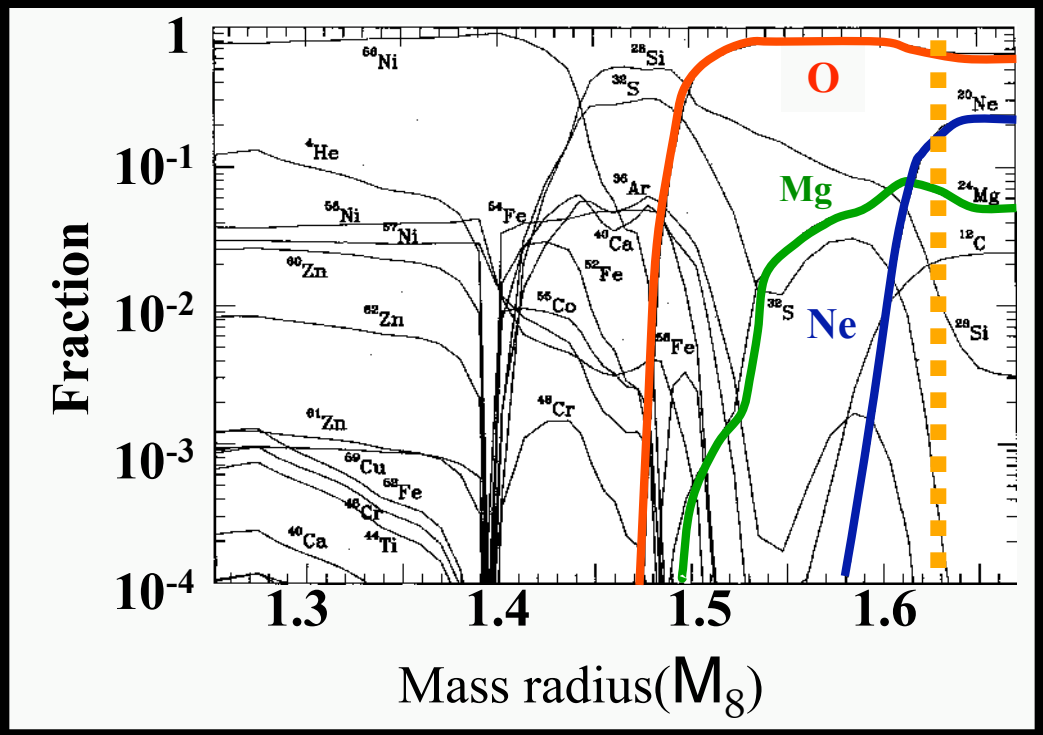
- East
  - kT_e ~ 0.2keV
  - Abundance : 0.01~1 x cosmic
  - High n_e and P

⇒Swept-up ISM

- West
  - kTe ~ 0.3keV
  - O~5, Ne~10, Mg~10
  - Fe~ 1
  - Uniform abundance

⇒Ejecta from the SN

Comparison with model



- Model calculation for Type II
- (Thielemann et al. 1996)
- M=13M_8

- O ~ 5, Ne ~ 10, Mg ~ 10 while Fe ~ 1
- Shrapnel D must come from r ~ 1.62 M_8

Estimation of the ejecta mass

- Estimate the mass in the FOV, Ω=20' x 20'
- Assume the depth of the plasma L is ~1.5pc

$$n=0.24\left(\frac{L}{1.5pc}\right)^{-1/2} cm^{-3}$$

$$M=4.4\times10^{31}\ g$$

$$=2.2\times10^{-2}M_{\odot}$$

- The shrapnel D is about 1/1000 of the entire ejecta (we assume the entire ejecta is ~$10M_{\odot}$)

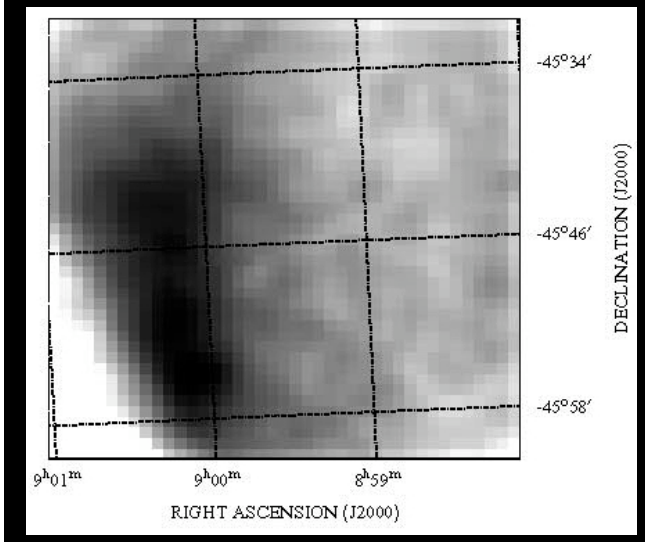
Summary of the shrapnel D

- We performed the observation of the shrapnel D near the Vela SNR.
- There is a discontinuity in intensity extending from north to south that coincides with the optical filament.
- Western part shows constant temperature (0.3keV) and abundance (O~5,Ne~10,Mg~10,Fe~1) that suggests the ejecta origin.
- Eastern part shows low temperature (~0.2keV) with low abundance (0.01~1 times cosmic value) that suggests the ISM origin.

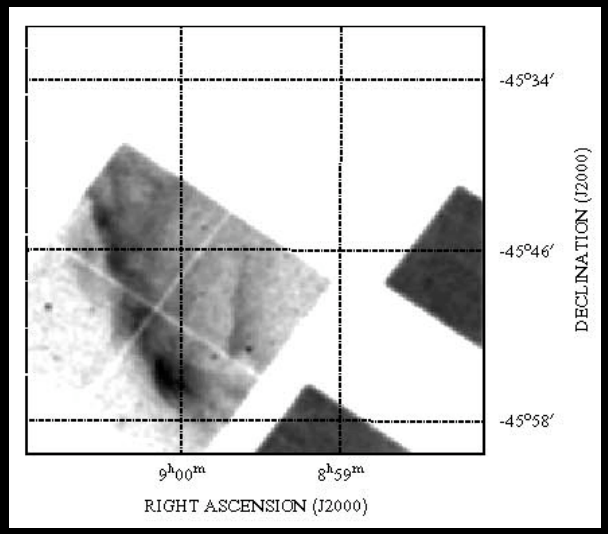
- **Middle-aged SNR (~10^4 years) still keeps its ejecta without merging with ISM.**

Comparison of images with instruments

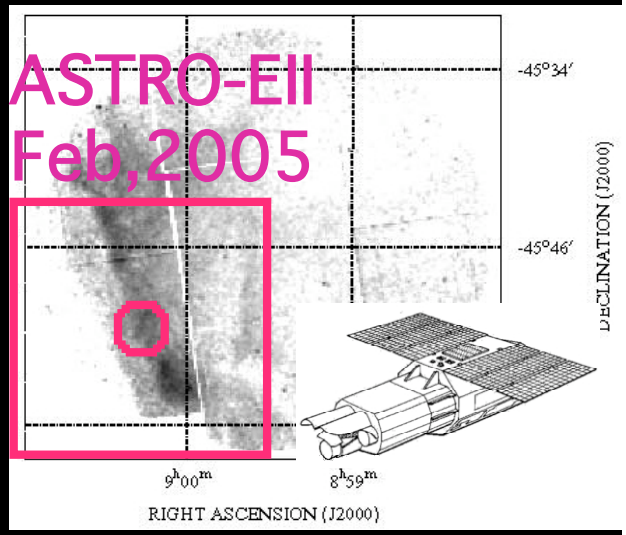
ROSAT PSPC



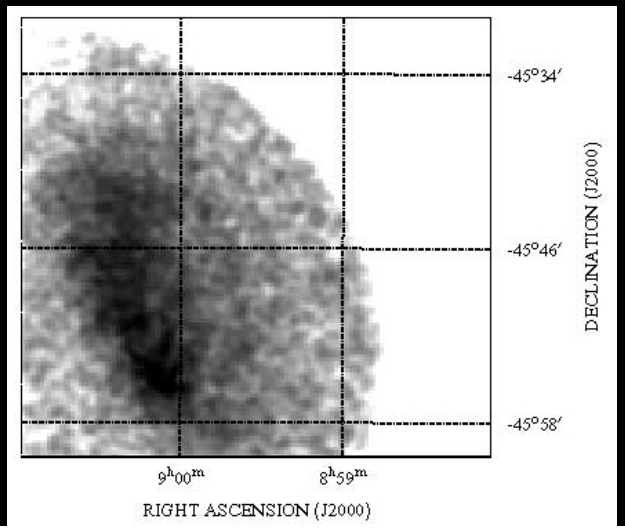
Chandra ACIS



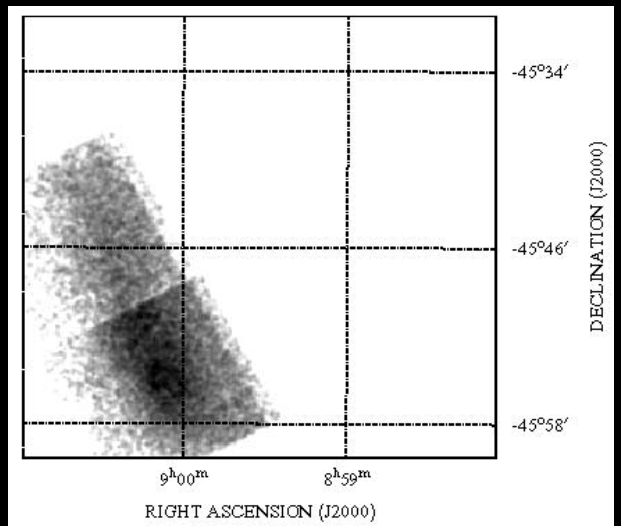
XMM-MOS



ASCA GIS



ASCA SIS



XMM-pn